A DISTRIBUTED PROCESSING/FIBER-OPTIC HOSPITAL INFORMATION SYSTEM

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Abstract

Progress in the development of a hospital information system that utilizes transaction-oriented distributed processing and an intelligent, fiber-optic-based local area communications network is reported in areas of system requirements, system design components and capabilities, and possible extensions of initial capabilities. A patient registration database organization and associated distributed data processing (DDP) transactions are described. The transactions are examined with respect to DDP functions, and process session controls embedded within a supporting communications network.

The separate development of a fiber-optic information exchange network is described in the areas of system architecture and embedded high level protocols. The ability of the communications network to manage processing sessions between hosts is utilized to manage transaction sessions in the hospital information system design. Installation and evaluation of an operational prototype fiber-optic LACN is planned for 1981 as support for networking four ancillary systems in a university hospital.

Introduction

Based on a recent survey report[1], approximately 2500 hospitals reported use, or planned use, of computer systems and/or services. Over 40 percent of the in-house computers reported were purchased, and extensive software support has been developed by the hospital staff for purchased and rented systems. Collectively this represents a considerable investment in computer support by hospitals. In addition, "the movement of computer applications beyond the traditional business office functions was quite apparent in the survey findings."[1] Thus, the commitment of hospitals to computer systems is seen as varied and extensive.

In this setting, interest is keen in improving performance of systems in-place, and in finding ways of improving coordination among diverse computer systems. Solutions are sought in "organizational technology [which] aids in the management and administration of medical care."[2] Proposed solutions to such problems as integrating computer systems and services should be judged partly in terms of their ability to improve the yield from original and future investments in computer technology without requiring major changes to existing procedures, or by dependence upon a new community of hospital computer systems experts. Efforts to contribute to such solutions have been ongoing at The Johns Hopkins University Applied Physics Laboratory for several years.

Integration of Computer Systems

Studies of hospital information system components of database organization, information flow and control patterns, subsystem integration and computer networking technologies[3,4,5,6] have led to a design for a low-cost, distributed processing, fiber-optic based hospital information system. This system design integrates functionally distinct computer systems, utilizing distributed database processing and control, and an 'intelligent' communications network. The main purpose of this paper is to describe that system with respect to selected design and performance requirements and the initial capabilities of a representative integrated hospital information system. The paper is organized into topic areas of

(a) system requirements
(b) system components including
  - a representative physical configuration,
  - distributed processing transactions, and
  - a fiber-optic local area communications network (LACN),

(c) extensions of initial system capabilities, and
(d) an implementation of the fiber optic LACN.

System Requirements

The selected requirements that form the basis of the system design for integrating heterogeneous computers are:

1. The composite system should provide immediate, recognized benefits in patient care "... by facilitating communication and reducing errors..."[7]. It should offer a simple, reliable, and easy to use communications capability with additional capacity to support processing functions such as data completeness, legibility and retrievability as defined by local user communities.[8,9].

2. The autonomy of participating computer subsystems should continue. No aspect of the integration design should preclude control

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of access to local processing resources by local user communities[5].

3. The hardware and software modifications to individual host computers, necessary to join the integration network, should be minimal[10].

4. The network communication subsystem should be low-cost off-the shelf technology. It should be easy to install and highly reliable. In order to realize the benefits of a standardized data base in a number of hospital settings[7,11] the hardware and software components of the communications subsystem should be highly adaptable for different computer systems.

Other requirements than these four are certainly possible. The selected requirements above reflect a narrowed view of a problem that admits to a first-order solution, with additional capacity built-in to achieve further incremental gains as experience is gained with integration and federation of heterogeneous systems.

System Design Components

Based on analyses of the requirements, and a separate engineering development of a fiber-optic communications network, a system design that will provide the required capabilities has evolved. The physical and logical components of the system are described in the three areas of (a) a representative physical configuration, (b) applications support, and (c) a fiber-optic local area communications network (LACN).

Physical Configuration

For purposes of illustration, a representative hospital information system has been selected to consist of a patient registration system, the three ancillary systems of pharmacy, laboratory and radiology, and a fiber-optic LACN. A possible configuration of these component systems is depicted in Figure 1. In Figure 1, the reader will note that each host computer system has its own data and its own user community (represented by computer terminals). Each host has one logical connection (although multiple data channels might be present) to a LACN which provides pathways to all other host subscribers. (The fiber-optic LACN is discussed in more detail in later sections.) The dotted line between the junction box (JB) components of the LACN signifies that the local area network can link subscriber systems separated by large distances.

Registration System

The idealized registration system serves as the owner and central controller of patient registration, admission, disposition and transfer (R/ADT) data. Replications of subsets of the R/ADT database may exist in other systems but only the R/ADT system has the authority to add, change, or delete entries to the composite or 'master' R/ADT database. The integrated system links all network subscribers to permit the capture, update, shared use, and deletion

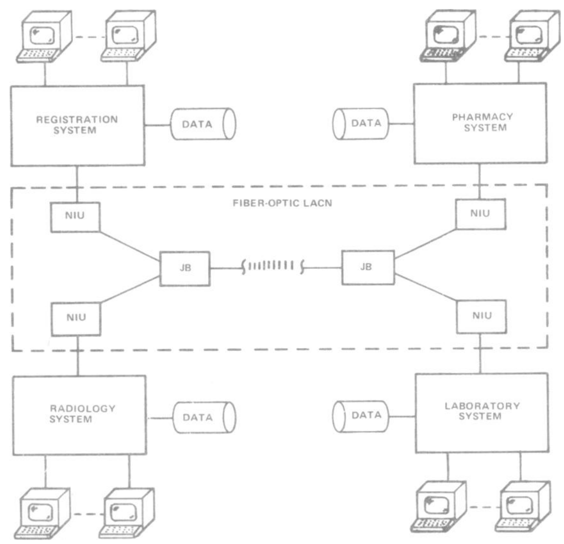

Figure 1. A Representative System

of patient R/ADT data. Enhancement of stand-alone capabilities in the separate work centers will be realized by reducing local R/ADT requirements through automated broadcast, exchange and update of patient information collected at a single location to all network subscribers. The registration system will retain control of the central patient registration data base and each of the ancillary systems will exercise control of its local subset of the patient registration data base.

Ancillary Systems

The Pharmacy, Laboratory and Radiology systems depicted in Figure 1 will continue to provide the same services to their local user communities as available before joining the network. In addition, each host connected to the communications network will be modified in software (hardware modifications are unnecessary) to support message and data base maintenance transactions as described below.

Fiber-Optic LACN

The physical pathway for communications among host subscribers is provided by a fiber-optic LACN. Referring to Figure 1, each host subscriber is connected to the network via a network interface unit (NIU) which is connected in turn to a junction box (JB) for directional routing of all signals. A more detailed description of the LACN is deferred until after a discussion of the intended applications of the network.

Distributed Processing Transactions

The success of a medical information system is likely to depend ultimately on the system's ability to support physicians with both current and historical patient data in a well-organized format. Systems development to satisfy associated requirements, such as collation of data from many sources, and incorporation of new episode data into a current medical record will require considerable effort over a period of years. As an underpinning for more comprehensive information support, sharing of patient registration information throughout a hospital is possible now through use of a simplified distributed data processing approach. The approach utilizes a single-owner master or 'central' patient registration data base, and replications of smaller subsets of that data at each ancillary. Functional applications programs within an ancillary host computer search local data bases first for patient registration information. If the information is not replicated locally, a message request is automatically placed across the network with the registration system. If the patient is not in the R/ADT database, initial entry of patient information may be accomplished by any network subscriber. Each host subscriber to the network shares patient registration data through use of a pre-defined set of processing messages. Patient registration information may thus be added or deleted locally in relationship to current needs, resulting in reduced on-line data storage and increased responsiveness.

The most general message processing method is to use transactions where each transaction is a single message containing both process control information and process data. For example, a transaction might contain the process code for requesting patient data plus the patient name to be used as the search field. All but the most specialized of communication exchanges can be managed through use of transactions.

The ability of each host computer system to process network transactions requires the following resident software functions:

(a) Validate appropriate data fields in a transaction,
(b) Initiate or reactivate an applications program upon receipt and validation of a transaction,
(c) Provide a response for process requests that cannot be satisfied, and
(d) Modify and communicate changes in system status.

Each host system joined to the local network achieves a functional interface with all other hosts through the use of a fixed set of transactions. The four classes of Request, Response, Unsolicited data, and Control transactions have been developed in detail to support the sharing and management of a distributed patient registration data base. Table 1 lists possible transactions in each of the four classes for sharing a patient registration database. A brief example of their use follows.

Providing services to a patient at an ancillary system requires a check of local files first to determine if that patient is currently 'known' to the ancillary. Referring to Table 1, if the patient is not registered locally, a 1A transaction containing the patient's name is generated internally and sent from the ancillary to the registration system (the local user need not be aware of this action). The registration system returns one or more 3A transactions (including the patient data) if the patient is registered, or a 3B transaction if the patient is not registered. Upon notification that the patient is not currently registered, the

Table 1. Transactions

Class	Number	Description
Request	1	Request for patient registration data
	1A	- Search by name provided
	1B	- Search by number provided
	2	Request for patient ID block(s)
	2A	- Generic search by last name
	2B	- Generic search by partial number
Response	3	Patient Registration Data Transfer
	3A	- In response to Type 1
	3B	- Null response to Type 1
	4	Patient ID block(s) transfer
	4A	- In response to Type 2
	4B	- Null response to Type 2
	5	Processing response to originator
	5A	- Transaction passed edit and validation checks
	5B	- Transaction rejected (reason code)
	5C	- Transaction has completed processing
	5D	- Transaction not processed (reason code)
Unsolicited Data	6	- One-way message
	6A	- New registration data
	6B	- Update notice from R/ADT
	6C	- Routine element update from ancillary
	6D	- Transfer of admission data
	6E	- Transfer of disposition data
	6F	- Transfer of data element change (can only be sent by owner of data element)
	6G	- Delete notice from ancillary
	6H	- Archive notice from ancillary
	6I	- Archive recall of patient registration of ancillary
Control	7	Notice to addressed system to change value of a network parameter
	8	Subsystem status change (start, restart, imminent crash)
	9	Transaction processing errors

ancillary system operator may capture necessary patient information and relay it to the central database using a 6A transaction. Whenever the ancillary operator wishes to delete a patient from local files he sends a 6G transaction to the registration system. Control transactions are for management of the network system. They are used to open, close or modify the connection between each host and the network, and are transparent to general users of the system.

The four classes of transactions require different levels of processing in host computers. Control and Unsolicited Data transactions are unitary events and are not coupled to a particular reaction from their destinations. Request and Response transactions, however, are coupled and require intermediate validation processing, and search and formatting processing. During that period of time between initiation of a request and receipt of a valid response, the process control and data elements must be saved somewhere. In addition, if a request cannot be serviced within a user-defined period of time, the user must be informed with options for reinitiating the request or termination.

In order to minimize the demands upon host systems for management of transaction sessions, a network communications system capable of managing interprocess sessions is required.

A Fiber-Optic LACN

In a separate research and development effort,[6] a fiber-optic local area communications network (LACN) system with the requisite transaction session management capabilities has been designed. It will support a wide range of networking applications by incorporating a number of desired networking features into one design. These features include:

(a) high data transfer capacity and speed,
(b) secure, reliable medium (immune to electromagnetic intrusion or extrusion),
(c) low cost off-the-shelf technology, and
(d) extensive communications services independent of type of host or level of host support.

These features are reflected in a fiber-optic duplex contention bus topology and distributed access control via network interface units (NIU).

Description of the NIU

The NIU is a microprocessor-based device that serves as a physical and logical interface between its parent host and the network on one side, and, on the other side, as manager of distributed data communications exchange between itself and other NIUs. The logical design and operations of the NIU reflect structured design techniques applied to the layered data communication protocol functions identified in the ISO reference model.[12] Seven layers of protocol are supported by the NIU, from the physical and data link connections for passing bits and bytes at the lowest levels through routing, transport, session control, presentation and application high level protocols for providing complete communications services between users.

A general problem in networking is the location of protocols in a network.[13,14] In a contention bus topology with distributed control, each node fulfills protocol requirements for communications with other nodes (a node consists of NIU plus parent host device). Within a node however, local area networking approaches generally allocate responsibility for high level protocols to hosts.[15,16,17] A significant problem associated with host management of high level communications protocols is the reconciliation by a local operating system of needs of the protocols with local processing needs. In addition, small scale systems may be excluded from joining the network if the resources to support high level protocol management exceeds local capacity.

In order to examine the feasibility of managing all or part of the high level communications protocols external to host subscribers, a computer model for transaction-oriented distributed processing was developed and exercised at JHU/APL. The modelled protocol structure functions independent of local operating system peculiarities and has demonstrated the feasibility of performing process-session management within a NIU.

Based on the modelling results and the general requirement to develop a network offering extensive communications services to subscribers, an NIU has been designed to support interprocess connection and session management.

Figure 2 is an illustration of the logical protocol design of a general-purpose NIU. Briefly, the NIU is composed of an upper and lower half (two separate microcomputers are used in the initial design). Each half functions asynchronously to support different levels of data communications protocols. One-time storage of data for use by both halves of the NIU is achieved through use of shared memory. As an example of NIU operation, a

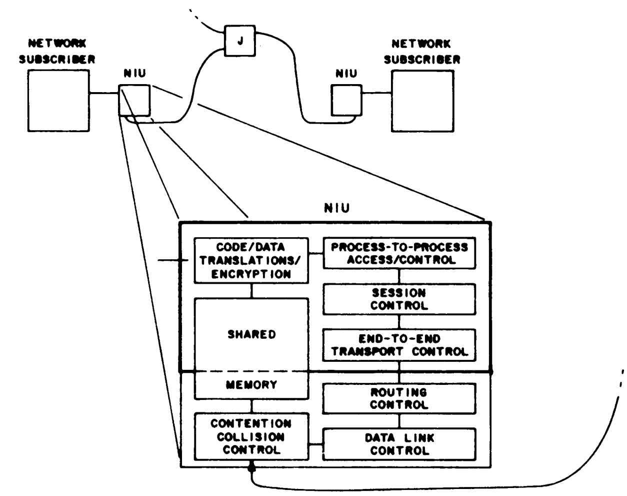

Figure 2. NIU Protocol Design

connection and processing session between network subscribers is negotiated (or is fixed by default) between the host user and NIU and between correspondent NIUs using the process-to-process and session control modules. Following this establishment phase, data may be exchanged between host users on a pathway from originating host (e.g., a terminal) across the physical and data link interface to the NIU, through a custom-designed code/format (encryption is optional) conversion module, through memory and across the fiber-optic channel into shared memory of the destination NIU, and, finally, through another custom-designed code/format conversion module into the I/O area of the destination host. Control of the movements of data along this path is affected by the separate control modules in the NIU. The process control module establishes, monitors and disestablishes connections between processes. The session control module, using parameters provided by the process module, establishes and maintains process sessions (e.g., two hosts 'taking turns' in processing, or one host requesting a service from another). The end-to-end transport control module supports sessions between processes by ensuring accuracy and sequencing of one or more messages constituting part of a session (e.g., a response to a request may entail three full screens of data). Routing and data link control modules ensure proper addressing and assured accurate delivery of network data units (called packets), and the contention/collision control module regulates access to the net and retransmission of packets that collide on the net.

In terms of the integrated hospital system application, Figure 3 is an illustration of the functional relationship of the NIU with its high level protocols condensed into transaction and control protocols, to the parent host and its input/output handlers, operating system and data calls. Each of the four hospital computers serves its local user community in a dedicated or time-sharing mode of operation. For an active process running on the host computer, calls are placed, usually through utility functions or subroutines, for data from local databases and files. When connected to the network, a modification to the data call function is required in each ancillary to take unsatisfied calls for local registration data, build a request transaction and place a call for writing the transaction to the NIU. When the NIU is ready to accept another transaction from its parent host, the transfer is made across a physical and data link path to the NIU. Upon acceptance of the transaction the NIU then assumes responsibility for a proper response or an error message. On the return path, the NIU signals the host I/O handler when a transaction addressed to a resident of that host is available for transfer. When signalled that the host is ready to receive, the NIU makes the necessary code/format changes and transfers the transaction.

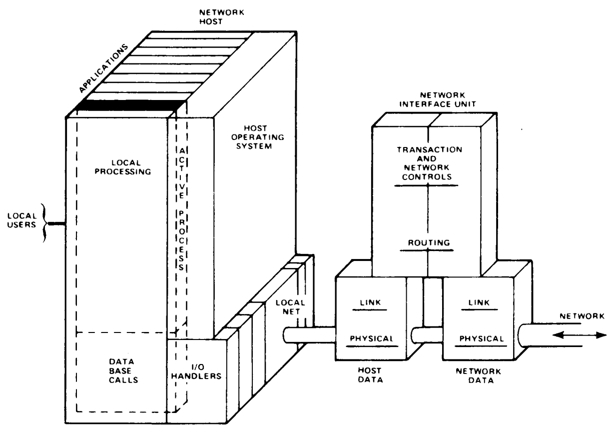

Figure 3. A Functional Node

Sharing of a central patient registration database and providing general conversational communications by the combined use of a pre-defined set of transactions and the fiber-optic LACN system is feasible for a collection of hospital systems. To achieve true distributed data processing capabilities,[18] extensions of this initial fixed transaction capability will be required.

Extensions of Initial Capabilities

Because the general purpose NIU design is robust, extensions of the initial capabilities of the hospital information system outlined above are possible. They include:

(a) Expansion of data carried within transactions to permit collation of separately owned data fields into composite records. A principle of 'data element ownership' may be used to achieve control of data validity.

(b) Use of NIUs as terminal cluster devices for remote access to all network hosts or other terminal clusters.

(c) Use of an NIU as an interface to time-sharing computer services external to the hospital and,

(d) Use of NIU general communications services to support more sophisticated process connections and session management such as word processing, electronic mail and central billing.

The desirability of these and other possible extensions of the initial capabilities is best determined by the user communities of each hospital that might choose to implement this approach to an integrated system.

An Implementation

Utilizing locally defined applications transactions for sharing several databases, an implementation of the fiber-optic LACN system in support of an integrated hospital system is planned for 1981. This application will initially integrate three ancillary systems and one registration/identification system, built by three different manufacturers each with different operating systems. Four NIUs, two junction boxes and approximately 400 meters of bi-directional fiber-optic cabling will be utilized. The cost of this implementation of the LACN, including customized NIU interfaces, NIU software for transaction-oriented processing, and installation and checkout is less than $100,000. This cost in relationship to the expected yield from the integrated system is considered low enough to satisfy the initial system design requirement.

Conclusion

A system for integrating heterogeneous hospital computers utilizing a fiber-optic local area network is feasible. The initial system capabilities satisfy selected requirements for a low cost and highly adaptable system through the use of pre-defined processing transactions and a host-tailorable network interface. As desired in individual hospital settings, extensions of the initial capabilities are possible to achieve greater distributed data processing capabilities in which computer services and resources as well as databases may be shared.

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